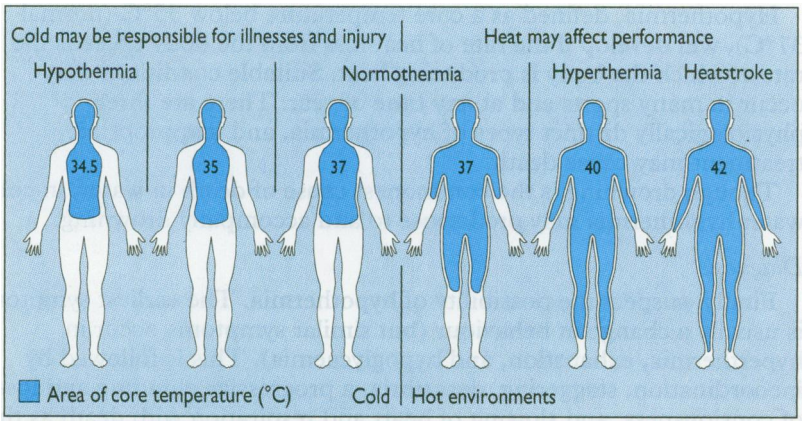
TEMPERATURE AND PERFORMANCE I: COLD

Evan L Lloyd

Environmental temperature may cause problems through being either too cold or too hot; and the effects may be general, local, or secondary. These effects range from impairment of performance through injury or illness to possible death, either directly or indirectly.

The effects of extreme cold in sport are more prevalent than are the results of extreme heat. For instance, for most sports in the world one of the numerically greatest hazards of cold is torn muscles or tendons. Hypothermia is also more common in Britain than is heatstroke. At milder degrees, cold can result in illness, injury, and death, whereas heat generally merely affects performance.



Rough relation of core temperatures and shell sizes. (Note the arbitrary temperature definition of hypothermia (<35°C) and the range of shell sizes in normothermia.)

Wind chill chart showing the effect of wind on increasing the degree of cooling at any particular temperature and wind speed

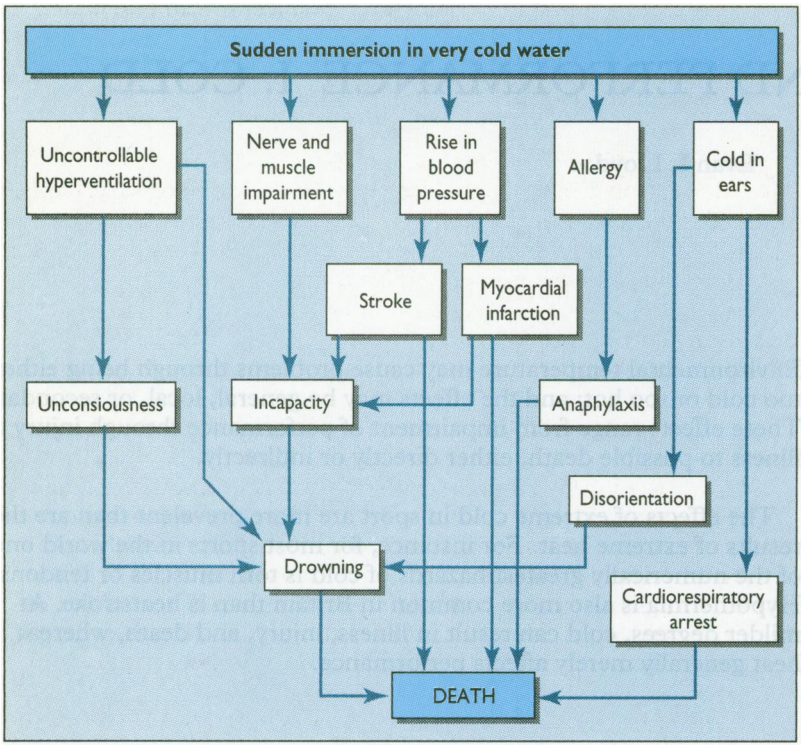
Wind speed (mph)	Equivalent chill temperature (°C)									
0	4	−1	−7	−12	−18	−23	−29	−34	−40	−46
5	2	−4	−9	−15	−21	−26	−32	−37	−43	−48
10	−1	−9	−15	−23	−29	−37	−34	−51	−57	−62
15	−4	−12	−21	−29	−34	−43	−51	−57	−65	−73
20	−7	−15	−23	−32	−37	−46	−54	−62	−71	−79
25	−9	−18	−26	−34	−43	−51	−59	−68	−76	−84
30	−12	−18	−29	−34	−46	−54	−62	−71	−79	−87
35	−12	−21	−29	−37	−46	−54	−62	−73	−82	−90
40	−12	−21	−29	−37	−48	−57	−65	−73	−82	−90
	Little danger			Increasing danger Flesh may freeze within one minute			Great danger Flesh may freeze within 30 seconds			

10 mph=16·1 km/h.

The body normally maintains a steady deep (core) temperature of 37°C, though the set point changes during the circadian rhythm, after sleep loss, during hypobaria (at altitude), and after dehydration. This stability is achieved by balancing the rate of heat production (mainly from metabolic heat generation) with the rate of heat loss and also by altering the temperature of the superficial tissues (shell). The size of the shell also varies. Heat transfer to and from the body follows the normal rules of thermodynamics. The rate of dry heat loss (convection and conduction) depends on the temperature difference between the skin and the environment. The rate of evaporative heat loss (surface evaporation and through breathing) depends on the ambient humidity. Air movement (air over the body or the body through the air) increases both types of heat loss.

When estimating the severity of cold stress—that is, the rate of heat loss—wind and wet are as important as temperature. A body is in fact losing more heat at +10°C in a 20 mph wind than at −10°C in still air. The time between exposure and damage is affected by the rate of heat production, and the deleterious effect of cold is reduced by insulation such as clothing. Exposure to cold causes the superficial and limb blood vessels to constrict to conserve heat. This reduces heat loss by reducing the difference between skin and environment temperatures. The temperature falls with increasing altitude (1°C/150 m).

Acute effects of cold



Sudden exposure to cold may result in death before there is any drop in core temperature. If death is caused by immersion in cold water it may be secondary to incapacity that leads to drowning.

Some people have an allergy to cold (often unsuspected) and sudden exposure may cause death through anaphylactic shock.

Sudden entry into very cold water produces pronounced cardiovascular responses that possibly lead to immediate death or incapacity from stroke or myocardial infarction.

Sudden severe cold of the skin also produces uncontrollable hyperventilation. The decrease in arterial CO_2 may lead to impaired consciousness, and even fit young people may be disabled by tetany. There is therefore a high risk of drowning. Even if a person is fully submerged it is impossible to prevent hyperventilation.

Swimming is difficult if not impossible in very cold water and even Olympic class swimmers become incapacitated, probably because of the effect of cold on nerve and muscle function. The effects are reduced if a person is acclimatised to cold immersion by habituation training.

Very cold water in the ears or nose may cause a vagal reflex with instantaneous cardiac and respiratory arrest. Cold in the ears may also lead to disorientation, which can cause submerged people such as capsized canoeists to swim downwards instead of towards the surface.

Hypothermia

Types of hypothermia

Immersion—Very severe cold stress occurs, for example, in a sailor or canoeist who capsizes

Exhaustion—Less severe cold stress, most frequently a combination of wind and wet with moderately low temperatures. Usually found in mountaineers or hill walkers but also in cross country skiers, runners, cyclists, and others who participate in endurance events

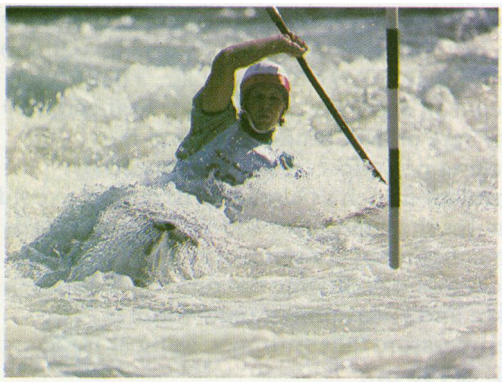
Urban—Cold is relatively mild but prolonged. Most common in elderly people or those with malnutrition but not in normal sport

Hypothermia, defined as a core temperature below 35°C (normal 37°C), will develop if the rate of heat loss from the body exceeds the rate at which the body is producing heat. Suitable conditions may occur in many sports and at any time of year. There are three physiologically distinct types of hypothermia, and inappropriate treatment may cause death.

Though drowning is the commonest cause of death in water, in cold water hypothermia may predispose to and accompany drowning.

Diagnosis

Firstly, suspect the possibility of hypothermia. The earliest symptom is usually a change in behaviour (but similar symptoms occur in hyperthermia, exhaustion, and hypoglycaemia). This is followed by incoordination, staggering, dysarthria, a progressive clouding and loss of consiousness, and slowing of heart and respiration with death as the final outcome. Accurate diagnosis can be made only by measuring the core temperature, usually rectally, but the necessary low reading thermometer is unlikely to be available where casualties occur. For practical purposes a casualty should be treated as a "cold casualty" if the body feels "as cold as marble," particularly if the armpit is profoundly cold.



Management before admission to hospital

With all three types of hypothermia, prevent further heat loss by removing the casualty from the cold environment. Movement must be gentle to avoid triggering a cardiac arrest, but in a severe environment such as cold water the priority is to get the person out of the cold. Until the casualty is indoors wet clothes should not be removed, but layers of insulating material should be put on top of the clothing and covered with a layer that is water and wind proof. The head must be included. Space blankets are often recommended but are no more effective than a similar thickness of very much cheaper polythene. These measures will probably be sufficient in immersion hypothermia. If available, airway warming (the inhalation of warmed moist air) should be used. This treatment is of particular value in exhaustion hypothermia where it will prevent the sometimes fatal cardiovascular collapse that may occur during rewarming. Moderate surface warmth is dangerous in

Indications for starting cardiopulmonary resuscitation in hypothermia

(1) No carotid pulse is detectable for at least one minute

OR

Cardiac arrest is observed—that is, a pulse disappears—or there is a reasonable chance that cardiac arrest occurred within the previous two hours

AND

(2) There is a reasonable expectation that effective cardiopulmonary resuscitation can be continued, with only brief periods of interruption for movement, until the casualty can be transported to hospital, where full advanced life support can be provided

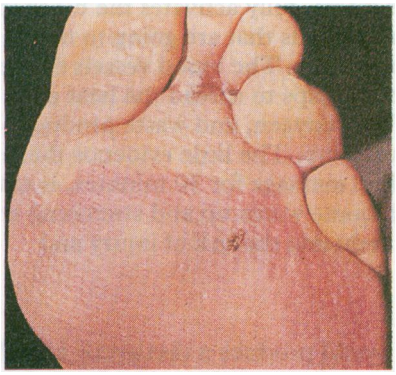
exhaustion hypothermia. Casualties with hypothermia should be taken to hospital for rewarming with intensive care monitoring. With urban hypothermia no additional heat, either surface or central, should be supplied before admission to hospital as this will precipitate fatal pulmonary or cerebral oedema or both, by reversing intercompartmental fluid shifts. These shifts can be monitored and controlled in intensive care.

Resuscitation after hypothermia

Respiratory obstruction should be cleared and, if necessary, expired air ventilation started using the same criteria and rate as in normothermia. Cardiopulmonary resuscitation, at the same rate as in normothermia, should be started if indicated.

Casualties totally submerged in very cold water, especially those who are young, have been known to recover even after submersion of up to one hour. Resuscitation must start immediately on rescue.

Local effects of cold



Cold rigid foot without sensation or digital motion. Note marks of sock texture. Extensive clear blisters developed, which became black when dry but finally sloughed off leaving normal function and anatomy. (Blood filled blisters, however, are a bad sign.)

Frostbite

Frostbite is a localised lesion caused by freezing. It preferentially affects the periphery—feet, hands, ears, nose, and cheeks—though the cornea has been affected in downhill skiers and speed skaters not protected by goggles. Penile freezing can occur during skiing or running in tight or inadequate clothing or from direct contact with a metal zip. Anything that restricts the circulation, such as tight training shoes, increases the risk, as does dehydration, excess tiredness, and altitude.

In *frostnip* the exposed skin, which has been painful, blanches and loses sensation but remains pliable. The part should be warmed by placing it in the armpit or under clothing. The part tingles, becomes hyperaemic, and within a few minutes sensation is restored and normal activity can be resumed.

In *frostbite* the tissues are hard, insensitive, and white or mottled. No attempt should be made to thaw frostbite if there is any chance of the part becoming refrozen because freeze-thaw-refreeze causes more damage than continuous freezing. It is safer to walk on frozen feet even for 72 hours.

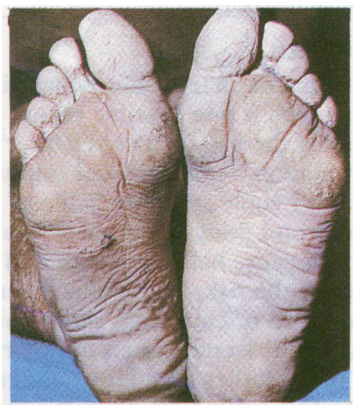
Treatment—Rewarming is ideally done in a hot (40°C) whirlpool bath, with gradual spontaneous rewarming as second best. Beating, rubbing with snow, or rewarming with excessive heat produce disastrous loss of tissue. Because damage from frostbite is usually more superficial than first suspected, debridement or amputation should be delayed for up to 90 days till mummification and demarcation are complete. After recovery the sufferer can return to full activity limited only by any tissue loss.

Trench foot

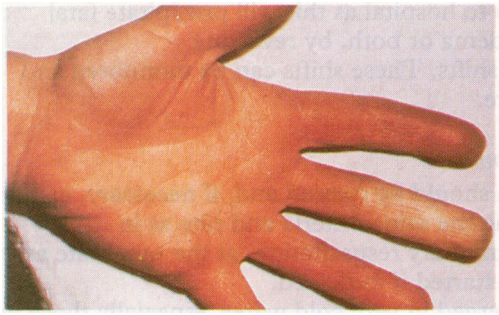
This is the most usual title for non-freezing cold injury (others include immersion injury, paddy foot, tropical immersion foot, and peripheral vasoneuropathy after chilling). Damage, which involves demyelination of nerves and possible muscle necrosis and atrophy, develops over a fairly long period when the legs are exposed to cold (above freezing) or wet, or both—for example, prolonged walking in boggy ground or sweating in impervious boots. As in frostbite, damage is more likely if there is fatigue, dehydration, immobility, and tight footwear. The feet are initially cold and numb, giving the sensation of "walking on cotton wool" and the combination with joint stiffness causes the victim to walk with legs apart to maintain balance. When first seen the feet are cold, swollen, and blotchy pink-purple or blanched.

Treatment—Remove the person from the hostile environment and allow the part to rewarm spontaneously. After rewarming feet become hyperaemic, hot, and red with

Hands less than 24 hours after frostbite thawed by using excess heat (boiling water in this case). Hands are cyanotic, painful, and foul smelling and there are no blebs. Resulted in spontaneous amputation at the metacarpophalangeal junction at six weeks.



Trench foot after rescue. Hyperaemia, swelling, distal cyanosis and anaesthesia, and aching and burning pain.



Other effects of cold

Warm up to prevent muscle injury

Flexibility—stretching
- Main muscles that will be used in sporting events
- Power muscles
- Vulnerable muscles and tendons such as hamstrings

Muscle warming—exercise till:
- Limbs feel "glowing warm"
- Slight feeling of breathlessness

Other effects of cold exposure

Muscular
- Muscle and tendon tears
- Shivering

Cardiovascular
- Angina on decreased exertion
- Rise in blood pressure—increases risk of:
  - Stroke
  - Myocardial infarction
  - Heart failure

Respiratory
- Asthma
- Rhinorrhoea on return to warm room

Peripheral nervous system
- Loss of manual dexterity
- Loss of sensitivity

Central nervous system
- Coordination impaired
- Visual acuity reduced
- Alertness reduced
- Reflexes slowed
- Increased mistakes
- Visual and auditory sensory input misinterpreted
- Hallucinations

Other
- Increased risk of "bends"

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paraesthesia or pain which may be severe (like electric shocks) especially on weight bearing. This may last for weeks. Severe cases cause bleeding into the skin, ulceration, and blisters and may progress to gangrene.

Because of the nerve and other damage, there is likely to be persistent, or permanent, hypersensitivity to cold as well as anaesthesia or hyperaesthesia and problems with the bony structure of the feet.

Raynaud's syndrome

Cold at a severity that does not affect normal people causes severe arterial vasoconstriction in people with Raynaud's syndrome, most commonly affecting the fingers. In severe cases this may lead to digital ulceration and tissue loss. Protection from cold by suitable clothing (gloves and shoes) is usually sufficient, but chemical hand warmers or electrically heated gloves or shoes may be necessary. Patients are strongly advised not to smoke.

Muscle injury

Muscle and tendon tears occur when a person is cold, and inactive muscles are cold even in warm weather. When muscles are cold their action is inefficient and may be incoordinated and joints are stiffer.

Prevention—An active warm up, sufficiently energetic and prolonged to ensure that the whole body is warm, fully activates the biochemical reactions that produce energy in the cells that are going to be used, including the muscles used in breathing. The blood vessels to the active muscles also open up, which helps to spread the heat and ensures optimum transport of food, oxygen, and waste products. A hot shower is useless in place of a warm up. The little evidence there is suggests that massage, even skilled massage for 30 minutes, is mainly of psychological benefit, and adequate warm up and stretching are much more effective means for reducing the risk of injury and enhancing performance.

Shivering

Cold causes shivering which would produce a disastrous fall off in performance in events that need steadiness such as shooting or snooker.

Angina

Angina may be produced by activity in the cold though the same activity in the warm produces no angina. Angina is reduced if the respiratory tract is protected from the cold. Cold also increases blood pressure and thus the risk of stroke, myocardial infarction, and heart failure. These are important with the increasing participation of older people in sport.

Asthma

Breathing cold air may bring on asthma attacks, but this effect is related only to the respiratory minute volume and the cooling capacity of the air, and not to the exercise itself, except that the respiratory minute volume is increased by exercise. The risk of asthma is increased during a respiratory infection and reduced by improved fitness and by breathing warm moist air. Asthma is no reason for not participating in exercise or sport.

Other effects

Hands lose their dexterity and fingers are much less sensitive in the cold, which is one possible reason for rugby wing threequarters dropping the ball on a cold winter's day. Cold also impairs coordination, reduces visual acuity and general alertness, and slows reflexes. People are more liable to make mistakes in the cold and can misinterpret things they see or hear. Prolonged hypoxia or exposure to cold can cause hallucinations, and the combination of both at altitude increases the risk. These effects may be detrimental or disastrous—for example, in orienteering, ski jumping, diving, climbing, or prolonged arctic or subarctic human or dog races. Occasionally some people even take their clothes off after prolonged exposure, though as with Sergeant Evans on Scott's fatal Antarctic expedition this usually only occurs just before the person dies from hypothermia.

Cold also increases the risk of decompression sickness ("the bends") in divers.